VISTA, a thermogravimeter to measure dust and volatile from Dydimos

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**Basic principles: μ-thermogravimetry**

**TGA** is a widely used technique to study absorption/desorption and condensation/sublimation/frosting processes in several environments.

The **thermogravimeter** core is a Piezoelectric Crystal Microbalance (PCM), whose oscillation frequency linearly depends on the mass deposited on its sensible area.

The PCM temperature is regulated by an appropriate **heater**.

**VISTA** (Volatile In-Situ Thermogravimetry Analyzer) is a miniaturized thermo-gravimeter.
Scientific Goals

SG1: Monitor the residual fine dust released from the impact

Dust is continuously collected from VISTA. Sub-micrometric dust cannot be predicted by models, therefore an in-situ measurement is important. The occurrence of two VISTA PCM’s on different parts of the mother spacecraft or different cubesats, will allow monitoring the spatial distribution of the plume.
Scientific Goals

SG2: Water and organics content in the emitted dust

This measurement will allow obtaining information about occurrence of pristine materials in the asteroid surface/subsurface. A TGA will be applied in order to heat the crystal up to desorption temperature of physically adsorbed water (i.e. 423 K) and organics (i.e. 473-523 K).
Assessment of contamination

Hydrocarbons released by S/C or payload materials in Space could affect the planetary protection and reliability of measurements. VISTA would collect these contaminants, which would be discerned by different sublimation temperatures/enthalpies.

VISTA is able to detect the main contaminants revealed in previous space missions, e.g. water, aliphatic compounds, fluorine, hydrocarbon molecules, PAH molecules, monomethylhydrazine (produced by outgassing).

VISTA would be able to do a stringent contamination control near the sensitive element (electronics, payload, insulated wires, etc.)
VISTA (Volatile In Situ Thermogravimetry Analyser) is a µ-thermogravimeter developed by IAPS-INAF, Politecnico di Milano, IIA-CNR and has been:

- Selected in the **scientific package of MarcoPolo-R** (ESA Cosmic Vision 2015-2025)
- Selected for the project «**Evaluation of an In-situ Molecular Contamination Sensor for Space Use**» (ITT ESA contract)
- Selected for the project «**Development of a European Quartz Crystal Microbalance**» (ITT ESA contract)
- Studied for Phase A of **Marco Polo, MarcoPolo-R, Penetrator for JUICE**
- Proposed for **ESA Cosmic Vision study missions**, i.e. MoonLITE, European Venus Explorer, Titan Aerial Explorer, Akon, Nautilus, Joint Europa Mission, Castalia, MarcoPolo-M5
- Proposed for **lunar applications** (i.e. Luna26, L-DEPP)
Instrument concept

The VISTA crystals are equipped with two built-in resistors, acting as heater (H) and temperature sensor (RTD), respectively.

The possibility to measure the actual temperature of crystals with good accuracy is one of the main challenges of VISTA.

**MEU:** Electronic box, can be shared with other sensors of the scientific package

**Sensor head 1 (SG1, SG3):** Cryogenic PCM (built-in heater + built-in thermistor + proximity electronics)

**Sensor head 2 (SG2, SG3):** Thermal PCM to measure water and organic content in dust ((built-in heater + built-in thermistor + proximity electronics)
VISTA technical characteristics

*Light, small, cheap and low-power consuming*

The Main Electronics Unit can be shared with other sensors and this reduces the VISTA resources to the two sensor heads, only.

<table>
<thead>
<tr>
<th>Unit</th>
<th>SH1</th>
<th>SH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor type</td>
<td>Quartz Crystal Microbalance</td>
<td>GaPO₄ Crystal Microbalance</td>
</tr>
<tr>
<td>Resonant Frequency(MHz)</td>
<td>10</td>
<td>5.8</td>
</tr>
<tr>
<td>Mass [g]</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>Volume [mm]</td>
<td>50×50×38</td>
<td>35×35×25</td>
</tr>
<tr>
<td>Power [W]</td>
<td>1 W (peak); 0.12 (mean)</td>
<td>1 W (peak); 0.5 (mean)</td>
</tr>
<tr>
<td>Data rate</td>
<td>54 bit/ measurement</td>
<td>42 bit/ measurement</td>
</tr>
<tr>
<td>Operating Temperatures [K]</td>
<td>&lt;180</td>
<td>&lt;550</td>
</tr>
<tr>
<td>TRL</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>4.4 ng/cm² / integration time</td>
<td>100 ppm</td>
</tr>
</tbody>
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The VISTA breadboard and EM
Sensor heads calibration

The linearity between built-in resistance and temperature has been verified in order to guarantee the correct working of the built-in temperature sensor.

The PCM has been supplied to different voltages in vacuum. For each applied power, the crystal temperature has been inferred from the $R$ vs $T$ characteristic.

$P$ vs. $T$

Corresponding to 250°C
VISTA performance tests

Measurement of volatile amount in planetary regolith/dust

The mass of a regolith simulant (clay material) has been measured:

1. Before a controlled hydration
2. After the controlled hydration
3. After the TGA

In the two performed tests, the TGA measures show a very good agreement between the amount of water absorbed from clay during its hydration and the amount of released water after the heating (about 3%).
VISTA performance tests

Simulation of contamination in space

Deposition rate of different contaminant simulants (e.g. dicarboxylic acids) have been measured on a cold PCM.

The validation of the performed measurements has been verified by using the obtained deposition rates at different temperatures to retrieve the enthalpy of sublimation of the analysed compounds.
VISTA performance tests

Example: deposition of Adipic acid on the PCM and TGA curve

Measured enthalpy of sublimation (deposition): 131.8±1.2 kJ/mol

Measured enthalpy of sublimation (TGA): 135.3±1.3 kJ/mol

Literature value: 131 kJ/mol (Albyn 2004)
Conclusions

- **VISTA** is a low-mass, low-volume, low-power consuming instrument which is able to perform crucial measurements to constrain the Dydimos composition (in terms of volatile content in dust) and to characterize the dust plume.

- VISTA can assess the contamination issue.

- The current **TRL** of the instrument is 5/6.

- The VISTA heritage comes mainly from the MarcoPolo-R study and from CAM instrument development.